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## Estimating the Yield Curve for the Malaysian Bond Market Using Parsimony Method

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### Abstract

The yield curve is an indicative of the level element bonds in the world prices of fixed income securities investment. It is used to predict interest rate, estimating the price of a security and as an indicator of the balance between maturity and yield. This study focuses on the comparison level of accuracy and appropriateness of the yield curve by the time interval for selecting the best method for producing the bond market yield curve in Malaysia. There are three parsimonious models that were applied in this study, namely Nelson-Siegel (NS), Nelson-Siegel-Svensson (NSS) and Extended-Nelson-Siegel (NSE). This study applied the data from Malaysian Government Securities (MGS) for the three days which are 31 January 2015, 15 February 2015 and 28 February 2015. The yield curve generated by the price expectations derived from the three models were then analyzed by Statistical methods such as RMSYE, MSE, RMSE and  $R^2$ .

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## 1. Introduction

Bonds are important financial instruments and the largest contributor of financial market in Malaysia. It is a loan given to buyers of bonds by issuers (such as corporations and governments) and its price is determined by the yield curve, which is an indicator element in the world of fixed income securities investments. It is also used to predict the level of interest, estimating the price of a security and an indicator balance between maturity and yield. There are two methods often used by researchers to produce a yield curve namely Parsimonious and Spline method, Dutta, G., Basu, S. & Vaidyanathan, K. (2005). According to Lin, B. H. (2002), both of these methods fall under statistical or empirical techniques. The empirical technique aims to estimate the interest rate term structure by using appropriate data and also to get the function more robust yield curve (Chou, J. H., Su, Y. S., Tang, H. W. & Chen, C. Y., 2009).

Cubic spline method is a method that uses the number of spline functions for estimating the production of the yield curve at the point of contact for the time value of fall term and the result value, McCulloch, J. H. (1971). These are available through the approximation technique with polynomial pieces function. For parsimony method, Nelson-Siegel extended and Nelson-Siegel and Svensson are often used by financial institutions to examine the yield curve for bonds without interest, Manousopoulos, P. & Michalopoulos, M. (2007).

This study is intended to produce a more accurate yield curve for the pricing of a bond using the data of Malaysian Government Securities (MGS) by comparing the method of Nelson-Siegel, Extended-Nelson-Siegel and Nelson-Siegel-Svensson. There are 5 sections in this study. The first Section will describe the introduction of the study. Section 2 will explain the background of the study, while section 3 will discuss about the data and the methodology. Section 4 will discuss about the findings while Section 5 will discuss about the conclusions.

## 2. Background of Study

Parsimony method requires the estimation of parameters in each function such as a discount function, spot rate and forward rate (Chou, J. H., Su, Y. S., Tang, H. W. & Chen, C. Y., 2009). The method of Nelson-Siegel and Nelson-Siegel-Svensson are commonly used method that leads to the forward rate to represent the result value which is a single function monotonic nature used to estimate the yield curve, Manousopoulos, P. & Michalopoulos, M. (2007). The Nelson-Siegel approach using exponential functions was introduced by Charles Nelson and Andrew Siegel from the University of Washington to estimate the shape of the yield curve monotonically, bumpy and S-shaped, Nelson, C. R., & Siegel, A. F. (1987). In their study, Nelson and Siegel felt that the ability to estimate the level of the yield curve in the bond price is important. Bond price data used in their study had a high correlation value. Based on Krippner, L. (2015), the combination of the theoretical and empirical foundation shows that the Nelson-Siegel models may be applied for the term structure that has firm statistical and theoretical foundations in the literature.

In 1994, Svensson had added two parameters to improve the smoothness and the sharpness as well as increasing the yield curve shape (U-shape), Svensson, L. E. O. (1994). He felt that, although the original Nelson-Siegel equation gives a good shape of the yield curve for the selected data, but it is still not able to solve problems involving complex data sets. Later, the original Nelson-Siegel method has been improved by the addition of parameters for estimating the yield curve in Extended Nelson-Siegel method, Bliss, R. R. (1996). According to Bliss, Extended-Nelson-Siegel method with the 5 parameters will produce structural accuracy with longer maturities.

The studies on the estimation of the term structure of interest rates taking into account the liquidity of bonds that have been implemented for the Indian government with low bond liquidity levels, Dutta, G., Basu, S. & Vaidyanathan, K. (2005). The method used in this study is the Nelson-Siegel-Svensson, cubic B-spline and cubic spline with violence or smoothing spline penalty. Results showed that cubic B-spline method and cubic spline have larger errors compared to the Nelson-Siegel-Svensson. Both of these methods did not achieve the objectives for curve estimation. The studies on bond liquidity levels are also conducted on the Taiwan bond with small size of bond trading and the level of lower liquidity, Chou, J. H., Su, Y. S., Tang, H. W. & Chen, C. Y. (2009). Besides that, in USA, there are no arbitrary constraints for Nelson –Siegel yield curve model (Coroneo, L., Nyholm, k., & Koleva, R. V., 2011). This study compares each parsimony method of Nelson-Siegel, Nelson-Siegel-Svensson and Extended-Nelson-Siegel. The results indicate that the method of Nelson-Siegel-Svensson is better than the others.

### 3. Data and Methodology

This study was carried out without taking into account the liquidity factor by using MGS data (source: Central Bank of Malaysia), which is the most actively traded securities in the domestic bond market. This study also used the data on January 31, 2015, February 15, 2015 and February 28, 2015. The difference between the bond prices given by the model with the actual market price is denoted as (error term) and it will be calculated and minimized to produce a smoother curve.

#### 3.1. Nelson-Siegel Method

Nelson-Siegel method states that the estimated bond price equation is given as follows:

$$P^{NS}(m) = \sum_{i=1}^n CF_i \exp \left\{ - \left( \beta_0 + \beta_1 \left( \frac{1 - e^{-\frac{m}{\tau_1}}}{\frac{m}{\tau_1}} \right) + \beta_2 \left( \frac{1 - e^{-\frac{m}{\tau_1}}}{\frac{m}{\tau_1}} - e^{-\frac{m}{\tau_1}} \right) \right) \right\} \quad (1)$$

where  $\beta_0, \beta_1, \beta_2$  and  $\tau_1$  are parameters to be estimated based on the initial conditions.  $\beta_0$  represents the long-term interest rates.  $\beta_1$  and  $\beta_2$  also determine the form of the slope and curvature parameters.  $\tau_1$  determines the position or the presence of the arc.  $\beta_0, \beta_0 + \beta_1, \tau_1$  must be a positive value

#### 3.2. Nelson-Siegel-Svensson Method

The equation of bond price estimated under the rule of Nelson-Siegel-Svensson is given as follows:

$$P^{NS}(m) = \sum_{i=1}^n CF_i \exp \left\{ - \left( \beta_0 + \beta_1 \left( \frac{1 - e^{-\frac{m}{\tau_1}}}{\frac{m}{\tau_1}} \right) + \beta_2 \left( \frac{1 - e^{-\frac{m}{\tau_1}}}{\frac{m}{\tau_1}} - e^{-\frac{m}{\tau_1}} \right) + \beta_3 \left( \frac{1 - e^{-\frac{m}{\tau_2}}}{\frac{m}{\tau_2}} - e^{-\frac{m}{\tau_2}} \right) \right) \right\} \quad (2)$$

Where  $\beta_0, \beta_1, \beta_2$ , and  $\tau_1$  are defined as Nelson-Siegel method. Parameters  $\beta_3$  and  $\tau_2$  have the same meaning with  $\beta_2$  and  $\tau_1$ .

#### 3.3. Extended-Nelson-Siegel Method

The equation of bond price estimated under Extended-Nelson-Siegel method is given as follows:

$$P^{NSE}(m) = \sum_{i=1}^n CF_i \exp \left\{ - \left( \beta_0 + \beta_1 \left( \frac{1 - e^{-\frac{m}{\tau_1}}}{\frac{m}{\tau_1}} \right) + \beta_2 \left( \frac{1 - e^{-\frac{m}{\tau_2}}}{\frac{m}{\tau_2}} - e^{-\frac{m}{\tau_2}} \right) \right) \right\} \quad (3)$$

### 3.4. Estimation Parameter Model And Statistical Comparison

Parameter estimation such as  $(\beta_0, \beta_1, \beta_2, \beta_3, \tau_1, \tau_2)$  for each model performed by minimizing the difference between the expected bond prices with the prices of the bond market which is denoted by error term square:

$$\min_{\beta_0, \beta_1, \beta_2, \beta_3, \tau_1, \tau_2} \sum_{i=1}^k \varepsilon_i^2 \quad (4)$$

where  $\beta_0 > 0, \beta_0 + \beta_1 > 0$  and  $\tau_{1,2} > 0$ .  $k$  is the number of bond that was used in this study and  $\varepsilon_i$  is the difference between the expected bond prices with actual prices of bond in the market for bond  $i$ . This study applied the software of Microsoft Office Excel and Microsoft Excel Solver to minimize error. Statistical method such as RMSYE, MSE, RMSE and  $R^2$  are used in selecting the best model that produces accurate curve for all types of Nelson-Siegel model.

## 4. Result

Table 1. The Model Comparison on the Time Interval based on the RMSYE

	TOTAL	180-360	1-3	3-7	7-10	10-15	15-20
		DAY	YEAR	YEAR	YEAR	YEAR	YEAR
<b>31-Jan-15</b>	0.00359	0.00607	0.00480	0.00282	0.00109	0.00149	0.00205
	NSE	NS	NSS	NSE	NSS	NSS	NSE
<b>15-Feb-15</b>	0.00403	0.00821	0.00582	0.00291	0.00065	0.00075	0.00115
	NS	NS	NS	NSS	NSS	NS	NSS
<b>28-Feb-15</b>	0.00453	0.01053	0.00583	0.00266	0.00102	0.00122	0.00127
	NSS	NS & NSE	NSS	NS & NSE	NSS	NS & NSS	NSE & NSS

Table 2. The Comparison of MSE, RMSE and  $R^2$

MODEL	DATE	MSE	RMSE	$R^2$
NS	31-Jan-2015	0.74910	0.86551	0.98311
	15-Feb-2015	0.90555	0.95161	0.97979
	28-Feb-2015	1.08822	1.04318	0.97582
NSS	31-Jan-2015	0.68006	0.82466	0.98339
	15-Feb-2015	0.86469	0.92989	0.97909
	28-Feb-2015	1.07421	1.03644	0.97415
NSE	31-Jan-2015	0.75086	0.86652	0.98239
	15-Feb-2015	0.90537	0.95151	0.97898
	28-Feb-2015	1.08822	1.04318	0.97486

## 5. Conclusion

Overall, the Nelson-Siegel model-Svensson is the best model for the three days since MSE and RMSE are the lowest when compared with other models. The model is also able to produce more accurate yield curve for estimating the term structure of interest rates using data obtained from the MGS dated 31 January 2015, 15 February 2015 and 28 February 2015. Through the method of Nelson-Siegel-Svensson, the curve generated has the most minor differences with real curves bonds. This illustrates that the additional parameters will result in a more accurate yield curve and smoother. Produced curves also show the real situation of the term structure of the bond market. Regarding the purpose of bond pricing, it can be concluded that financial institutions can use the Nelson-Siegel model to estimate the prices of bonds with short maturity periods prior while Nelson-Siegel model-Svensson used to estimate the prices of bonds with long maturity periods prior.

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